AFTER THE FREMONT: FIRE AND VEGETATION HISTORY OF PREHISTORIC ABANDONMENT AND HISTORIC OCCUPATION OF RANGE CREEK CANYON, UTAH

by

Stacy Randolph Morris

A thesis submitted to the faculty of
The University of Utah
in partial fulfillment of the requirements for the degree of

Master of Science

Department of Geography

The University of Utah

December 2010

The Graduate School
THE UNIVERSITY OF UTAH

STATEMENT OF THESIS APPROVAL

The thesis of ____________Stacy R. Morris_______________________________
has been approved by the following supervisory committee members:

________Andrea R. Brunelle_______ , Chair _________05/13/2010_______
Date Approved

________Duncan Metcalfe_______ , Member _________05/13/2010_______
Date Approved

________Kenneth L. Petersen_____ , Member _________05/13/2010_______
Date Approved

______Larry L. Coats___________ , Member _________06/02/2010_______
Date Approved

and by_______Harvey J. Miller___________, Chair of the Department of_Geography

____

Charles A. Wight,
Dean of The Graduate School

ABSTRACT

Paleoecological reconstructions were used to analyze a low elevation wetland core extracted from Range Creek Canyon, Cherry Meadows, a location known to have Fremont habitation. The data presented here show the vegetation and fire regime changes within Range Creek Canyon from ca. A.D. 1166-1949, following the Fremont occupation, which centers on A.D. 1050. The fire and vegetation record shows low fire frequency and low pollen influx immediately postabandonment. This can be attributed to the Fremont performing annual maintenance burning for land management and agricultural purposes and/or decreases in woody fuels due to Fremont use of those resources. Around A.D. 1240 the record demonstrates the arboreal release of Salicaceae and Cupressaceae, and a steady increase in other economically significant taxa, such as Asteraceae, Fabaceae, Poaceae, Cheno/Ams, *Sarcobatus*, Rosaceae, Rosaceae/*Quercus,* and *Ephedra*. This postabandonment change in vegetation suggests the utilization of these taxa by the Fremont during occupation, and a subsequent recovery of these plants. In addition to changes in vegetation following the abandonment of Range Creek by the Fremont, the record shows a significant increase in charcoal influx, which is attributed to the lack of maintenance burning and the recovery of vegetation (fuel). The Euro-American settlement of Range Creek Canyon brings a return of low fire frequency, associated with the reintroduction of maintenance burning, the removal of woody resources for building and/or the arrival of cattle on the landscape. Evidence of Euro-

American settlement in the canyon is indicated by the appearance of Moraceae pollen at A.D. 1894.

Dedicated to my musician, magician, pibs and roo!

TABLE OF CONTENTS

LIST OF FIGURES

ACKNOWLEDGEMENTS

I would first like to thank my husband Jesse Morris for all his love and support, for reading countless copies of my thesis, editing copies with me, encouraging me and putting up with me! Thank you to my kids for being so sweet and always cheering me up when I needed it. I would like to thank my mom Dianne Randolph for all her help watching the kiddos for us and for her support to our family throughout my degree. I would like to thank my dad for instilling the love of earth processes in me and who was always there for me and continues to be in spirit. Thank you to Tim and Casey Morris for their support, even flying across the county to watch the kids for us. Thanks family! You guys were always there for me and I could not have completed this degree without you guys!

On the professional side, I would first like to thank my advisor Dr. Andrea Brunelle, for her support and guidance. She was instrumental in the completion of my degree and I could not have finished without her encouragement and help. Thank you to Dr. Duncan Metcalfe for allowing us the opportunity to conduct research down and Range Creek Canyon and for providing us the money for radiocarbon dates and a semester of RA work. His expertise and insight was fundamental to the completion of this research. Thank you to Dr. Kenneth Petersen for coming on board late and providing invaluable information, help and kind words. This paper was influenced heavily by his guidance. Thank you to Larry Coats for help in the field, the amazing photographs and his help and guidance editing this manuscript. Thank you to Jessica Spencer and Tim Edger for their help in the field and to the Geography staff for all their help.

CHAPTER 1

INTRODUCTION

Paleoecological methods, such as those utilizing lake and wetland sediments, offer an excellent opportunity to address and interpret habitation site abandonment and land use history from archaeological sites. Specifically, pollen and charcoal records offer interpretive power to help assess how past climate variability modified vegetative communities, and ultimately allow researchers to make inferences about how climate change might have influenced prehistoric people and their behavior (Lindsay, 1986; Bryant and Hall, 1993; Kelly, 1997; Benson et al,. 2007a, 2007b). Pollen and charcoal data can also provide information about how humans modified their environment, such as burning the landscape for land management (Pyne, 1982, 1995; Petersen and Matthews, 1987), removing trees from the landscape for building and heating/hearths (Adams and Petersen, 1999; Towner et al., 2009), and clearing the land for agricultural fields (Petersen and Matthews, 1987).

Archaeological pollen studies in the southwest have been applied to infer use of plant resources by analyzing residues from artifact washes and habitation sites (e.g., Anderson, 1955; Leopold et al., 1963; Martin, 1963; Hevly, 1964; Schoenwetter and Eddy, 1964; Martin and Byers, 1965; Schoenwetter, 1966, 1970; Wycoff, 1977; Madsen, 1979; Kohler et al., 1984; Kohler and Matthews, 1984; Hall, 1985; Petersen and Matthews, 1987; Adams and Petersen, 1999; Geib and Smith, 2008). Pollen has been collected and analyzed from depositional material in caves and alluvial settings and has been valuable in assessing usage of wild plant resources (Martin and Byers, 1965). Other archaeological studies have analyzed pollen obtained from sediment cores collected from wet areas within an archaeological site (e.g., Schoenwetter, 1966; Wyckoff, 1977; Petersen and Matthews, 1987). Sedimentary cores obtained in depositional settings, such as lakes, bogs and meadows, are useful in archaeological studies because pollen data from these cores can be used to reconstruct environmental and landscape conditions that coincided with the occupation period (Petersen, 1994).

The research presented here analyzes pollen and charcoal preserved in a sediment core retrieved from a perennially wet meadow in central Utah (Range Creek Canyon, Cherry Meadows) and is unique because it is the only continuous core from a low elevation archaeological site in this region. This study contributes to the understanding of how past climate variability influenced human habitation in the American southwest, and more specifically how it influenced and contributed to the postoccupation vegetation and disturbance history of Range Creek Canyon. This is also the first sedimentary charcoal record obtained for an archaeological habitation site in the southwest region.

Objectives

The research presented here uses fossil charcoal and pollen data from the analysis of a sediment core to examine the hypothesis that the Fremont used fire as a land management tool. The two questions to be addressed in this thesis are: 1.) How did the climate affect

Fremont occupation patterns? 2.) How did the Fremont affect vegetation and fire during their occupation and after abandonment?

Climate of the American southwest

The American southwest is a topographically diverse region with distinct seasonal patterns of moisture. Annual precipitation generally increases with elevation whereas average temperatures decrease with elevation (Anderson et al., 1999). An air mass boundary between summer- and winter-dominated precipitation exists at around 38 degrees north latitude, though this boundary is approximate and migrates in response to fluctuations of the dominant pressure cells in the Pacific Ocean (Mitchell, 1976; Petersen, 1994; Mock, 1996). Winter precipitation is generally derived from the north Pacific (Gulf of Alaska, Aleutian Low), and summer moisture generally arrives as convective or orographically uplifted airmasses with moisture derived from the North American monsoon (NAM). The NAM is a significant driver of vegetative communities in the Southwest. The strength of the monsoon, and therefore its intensity and northward propagation, are determined by differences in heating properties between the land surface and the adjacent waters of the subtropical Pacific Ocean, the Gulf of California and the Gulf of Mexico. As solar radiation increases during the northern hemisphere summer (June, July and August), the land surface warms relatively rapidly compared to the ocean and draws moist air parcels on shore from the proximal water bodies. The onshore flow of relatively cool, moist air is met with lower atmospheric instability as the air masses move over land. These air parcels rise due to the intensity of surface heating over land, and as they ascend release precipitation. On longer timescales (centuries to millennia), the strength and persistence of the NAM is controlled by changes in the earth's orbit, which modifies insolation (Milankovitch cycles). Reductions in insolation in the northern hemisphere mitigate the summer heating contrast between land and sea, and generally reduce the intensity and northward extent of the NAM.

In the late Holocene, at time scales shorter than those affected by orbital variations, are climate events such as the Medieval Climate Anomaly (MCA) and the Little Ice Age (LIA). In the Southwest between 800-1300 A.D, a climate period called the Medieval Climate Anomaly (MCA) has been described as having generally warmer temperatures and elevated summer monsoon-derived precipitation input due to an increase in solar irradiance (Hughes and Diaz, 1994). Monsoonal moisture migrated farther north, arrived earlier in the summer and persisted longer than previous or at present. The northward intrusion, length of time and earlier arrival of the NAM is likely to have supported maize agriculture and the expansion of the puebloan occupation throughout the southwest region (Peterson, 1994; Adams and Petersen, 1999; Coltrain and Leavitt, 2002). Severe droughts characterize the later centuries of the MCA (Cook et al., 2004; Benson et al., 2007a; Knight et al., 2009), and some suggest the late MCA droughts caused widespread abandonment of the habitation sites in the Southwest (Benson et al., 2007a, 2007b), while others have attributed the abandonment to the onset of the LIA (Porter, 1986; Petersen, 1994).

The onset of the LIA occurred during the late-Holocene between ca. A.D. 1300 to 1850. The LIA was caused by secular variations in solar output (Petersen, 1994). In the northern hemisphere, the LIA is characterized as being cooler and drier than the MCA (Hughes and Diaz, 1994; Petersen, 1994). During the LIA the American southwest was relatively dry in the summer as the northward extent and intensity of the NAM was reduced. Lowered temperatures not only limited the arrival of summer monsoon moisture but also reduced the number of frost-free days (Lindsay, 1986; Newman, 1996). The cooler, drier climate and fewer frost free days of the LIA limited the feasibility of dry farming agriculture across much of the American southwest (Petersen, 1994). Summer precipitation reconstructions using tree rings support drought conditions in the Southwest during the early LIA (Fritts et al., 1965; Cook et al., 2004; Knight et al., 2009). This period of droughts, as it relates to agricultural failure, is coincident with numerous site abandonments throughout the Southwest region (e.g., Wyckoff, 1977; Adams and Petersen, 1999). Relatively warm and moist conditions eventually returned, perhaps as early as the mid-LIA, which ultimately facilitated the re-establishment of dry farming practices in some regions of the southwest (Petersen, 1994; Benson et al., 2007a, 2007b).

Native American fire use

Throughout human history, fire has been used as a land management tool on nearly every continent (Pyne, 1982, 1995; Blackburn and Anderson, 1993; Keeley, 2002; Stewart, 2002; Abrams, 2008). Human prescription of fire on the landscape has shaped vegetative structure, and it is suggested that the repeated application of fire to ecosystems has evolved to a symbiotic relationship between humans and their surrounding environment (Pyne, 1982, 1995). While human use of fire is a global phenomenon across diverse landscapes, the reasons for its use are actually very similar. In addition to fire used in hearths for heat and food preparation, most cultures use fire to clear land for hunting game, increasing their water resources, increasing the yield of wild plant resources, for improving agricultural soil conditions, clearing land for settlement sites and also to help facilitate overland navigation (Pyne, 1982, 1995; Blackburn and Anderson, 1993; Keeley, 2002; Stewart, 2002; Abrams, 2008).

Information pertaining to aboriginal fire use exists for many areas of western North America, such as in the Rocky Mountains, and California (e.g., Barrett and Arno, 1982; Pyne, 1982, 1995; Russel, 1983; Stewart, 2002). However, surprisingly little is known about prehistoric use of fire by humans in the southwestern United States despite the wealth of archaeological remains to be found in this region. Much of the data that exist in other regions of North America have been assisted to some degree by accounts recorded in journals by Europeans observing aboriginal activities (e.g. Barrett and Arno, 1982; Russel, 1983; Denevan, 1992; Whitlock and Knox, 2002). Therefore, greater uncertainty surrounds many of the potential uses of fire by prehistoric cultures that existed many centuries prior to European arrival, such as the Anasazi and the Fremont (Stewart, 2002). This thesis will focus on generating an understanding a pre-Colombian record of fire and vegetation from a Fremont occupation site located in central Utah.

Native American vegetation use

Native Americans exploit and use a wide variety of native plants and domesticates and grow a variety of agricultural plants in the southwest (Martin and Byers, 1965, Madsen, 1979, Petersen and Matthews, 1987, Kelly, 1997, Coltrain and Levitt, 2002). Wild plants utilized by people of the southwest include Chenopodiaceae –Amaranthaceae (goosefoot/pigweed), *Helianthus* (sunflower), *Typha latifolia* (cattail), Campanulaceae (bellflowers), *Cleome* (beeweed), Ephedraceae *Ephedra Viridis* (morman tea), Brassicaceae (mustards), Portulaceae (purslane), Solanaceae (nightshade), Poaceae (grass) and Rosaceae (rose) (Martin and Byers, 1965, Madsen, 1979, Kelly, 1997). Agricultural plants typically found at archaeological sites being grown by Native people include: *Zea mays* (corn), Cucurbitaceae (squash), Fabaceae *Phaseolus* (beans) (Martin and Byers, 1965, Madsen, 1979, Kelly, 1997). Native American people also used different tree species such as Fagaceae (oak), Cupressaceae (juniper), and Salicaceae (willow) for food and heating, fires and as construction materials (Kohler et al., 1984, Kohler and Matthews, 1984, Petersen and Matthews, 1987 and Towner et al., 2009). Martin and Byers (1965) noted that disturbance species such as, Chenopodiaceae – Amaranthaceae, Poaceae and Asteraceae increase during occupational events, when Native people were clearing the land for agricultural practices.

Fremont

Fremont artifact assemblages are found primarily in Utah but do extend into the southeastern Idaho, southwestern Wyoming, northwestern Colorado and eastern Nevada (Barlow, 2002). These assemblages date from A.D. 200 to A.D. 1350, with the majority of sites dating between A.D. 700 and A.D. 1200 (Marwitt, 1986; Talbot and Wilde, 1989; Massimino, and Metcalfe, 1999). The Fremont are described as an archaeological complex instead of a culture, because “Fremont” occupation sites and related artifact assemblages vary from one another in many ways and lack a coherency that is typical of other well-defined prehistoric cultures.

However, similarities have been observed among Fremont sites, which support a group classification beyond geographic proximity (Madsen, 1989; Barlow, 2002; Coltrain and Levitt, 2002). The four main classification traits that are used to define the Fremont are: 1) Distinctive anthropic forms used in pictographs, petroglyphs and trapezoidal clay figurines. These artworks typically depict human figures with elaborate headdresses, necklaces, earrings and blunt haircuts (Morss, 1931; Aikens, 1966; Cutler and Blake, 1970; Marwitt, 1970; Winter and Wylie, 1974; Winter and Hogan, 1986; Madsen, 1989; Adams, 1994). 2) Thin-walled gray ceramics, some decorated with appliqué (Barlow, 2002). 3) A unique single-rod-and-bundle basketry style (Barlow, 2002). 4) Leather moccasins with soles that have the dew claw from a deer or mountain sheep (Petersen, 1969 and Barlow, 2002). Other artifacts associated with the Fremont archaeological complex not listed above include 8 to 14-rowed dent maize, regionally distinctive small projectile-points, “Utah-type” trough metates with a distinctive shelf and secondary grinding depression, and stone balls used for grinding or processing food (Morss, 1931; Aikens, 1966; Cutler and Blake, 1970; Marwitt, 1970, 1986; Winter and Wylie, 1974; Winter and Hogan, 1986; Madsen, 1989; Adams, 1994; Barlow, 2002).

Archaeological evidence suggests that the Fremont groups found throughout the Great Basin and Colorado Plateau were diversified hunters and gatherers that adopted agriculture and southwestern farming practices (Madsen and Simms, 1998). Along with the adoption of agriculture (specifically maize agriculture), Barlow (2002) hypothesized that the Fremont were employing a “slash-and-burn” strategy, which was also being used in Latin America at that time and knowledge of this practice may have been disseminated northward.

CHAPTER 2

SITE DESCRIPTION AND HISTORY

Range Creek Canyon

Range Creek Canyon (RCC) is located in central Utah in the Book Cliff-Roan Plateau section of the Colorado Plateau geologic province (Fig.1). Range Creek itself is a tributary of the Green River, which ultimately is the most significant tributary of the Colorado River. RCC is located immediately south of Nine Mile Canyon and is bounded by the Book Cliffs to the east and south. The Desolation Canyon portion of the Green River is located immediately to the east. RCC is topographically complex; the sandstone canyon walls are steep and rise up 300 vertical meters from the canyon floor. RCC lies on the border of Emery and Carbon counties in Utah.

Cherry Meadows is located within RCC inside the gates of the former Wilcox Ranch. The meadow elevation is approximately 1,525 m above sea level. Cherry Meadows is a perennial wetland that is fed by springs. The meadow is found within the floodplain of Range Creek, which runs through Cherry Meadows. Clusters of Fremont habitation sites surround the meadow, and it has been suggested that agriculture plots, such as those for maize, were likely to have been cultivated on the meadow due to persistent moist conditions. During field work, vegetation in Cherry Meadows was observed to be comprised largely of Cyperaceae (sedges) and Poaceae (grasses), with occasional clusters of Typhaceae (cattails). The forest community surrounding the meadow consists primarily of *Acer negundo* (box elder), *Populus deltoides* (cottonwood), *Juniperus osteosperma* (Utah juniper), *Juniperus scopulorum* (Rocky Mountain juniper), *Pinus edulis* (pinyon pine). Upslope from Cherry Meadows, the forest community is dominated by *Psuedotsuga mensizii* (Douglas fir), *Acer grandidentatum* (big tooth maple) with occasional specimens of *Abies concolor* (white fir).

Site history and occupation

Archaeologists Duncan Metcalfe and Kevin Jones, among many others, consider RCC the greatest archaeological discovery in North America in over a hundred years (Duncan Metcalfe and Kevin Jones, personal communication 2005). The significance of RCC derives from the large numbers of features and artifacts left behind by the Fremont and the pristine condition of the occupation sites within the gates. Radiocarbon dates for Range Creek Canyon are clustering around ~ A.D. 1050 (Metcalfe, 2008).

The rugged terrain of Range Creek Canyon limits public access except by two primitive roads, located at either end of the canyon where they are gated and locked. The acreage within and immediately around the gates of RCC are presently under the stewardship of the University of Utah (Metcalfe, 2008).

Assumptions about Fremont subsistence in RCC are drawn from observations of other habitation sites located throughout the known Fremont Culture region. The Fremont were adaptive and switched between hunter-gatherers and “farmer-foragers” (Spangler, 2000, Coltrain and Leavitt, 2002). It is assumed that the Fremont of RCC were both adept hunter/gatherers and agriculturalists. Evidence of Fremont agriculture is readily found in

RCC, including numerous large granaries, which when examined were found to contain corncobs along with packrat middens and have been reported to have contained squash and beans (Metcalfe, 2008).

Fremont habitation sites and artifacts have been found throughout RCC, from valley floors to rocky pinnacles located 300 meters above (Metcalfe, 2008). The greatest density of habitation sites (pit houses) has been observed on the valley floor of the canyon adjacent to Range Creek (perennial stream). These sites are situated directly in or at least in close proximity to a network of open meadows, which might have been ideal sites for agriculture during Fremont occupation of the canyon.

Another potential explanation for selecting habitation sites across an elevational gradient might reflect inconstant resource availability due to changing climate. Range Creek Canyon is located in a peripherally productive environment where seasonal precipitation and frost free days offer marginal climate conditions for sustaining agriculture. Similarly, modifications to moisture or temperature seasonality would have triggered adjustments in animal migration patterns (wild game) and/or availability of economic plant resources, which would have also complicated the subsistence of the human inhabitants of RCC. In the event that both temperature and moisture structure forced agriculture to be unproductive, a return to hunter/gatherer lifestyles might have been unavoidable. The transition of the NAM to a more southerly extent during the transition from the MWC and LIA would have undoubtedly disrupted Fremont subsistence strategies, and could have lead to an eventual abandonment of sedentary agriculture if moisture deficits were prolonged during the LIA. Less rainfall and shorter growing seasons would have limited resource production from agriculture which in turn would lead to decisions about locating habitation and food storage sites in inaccessibly to serve as a defensive strategy.

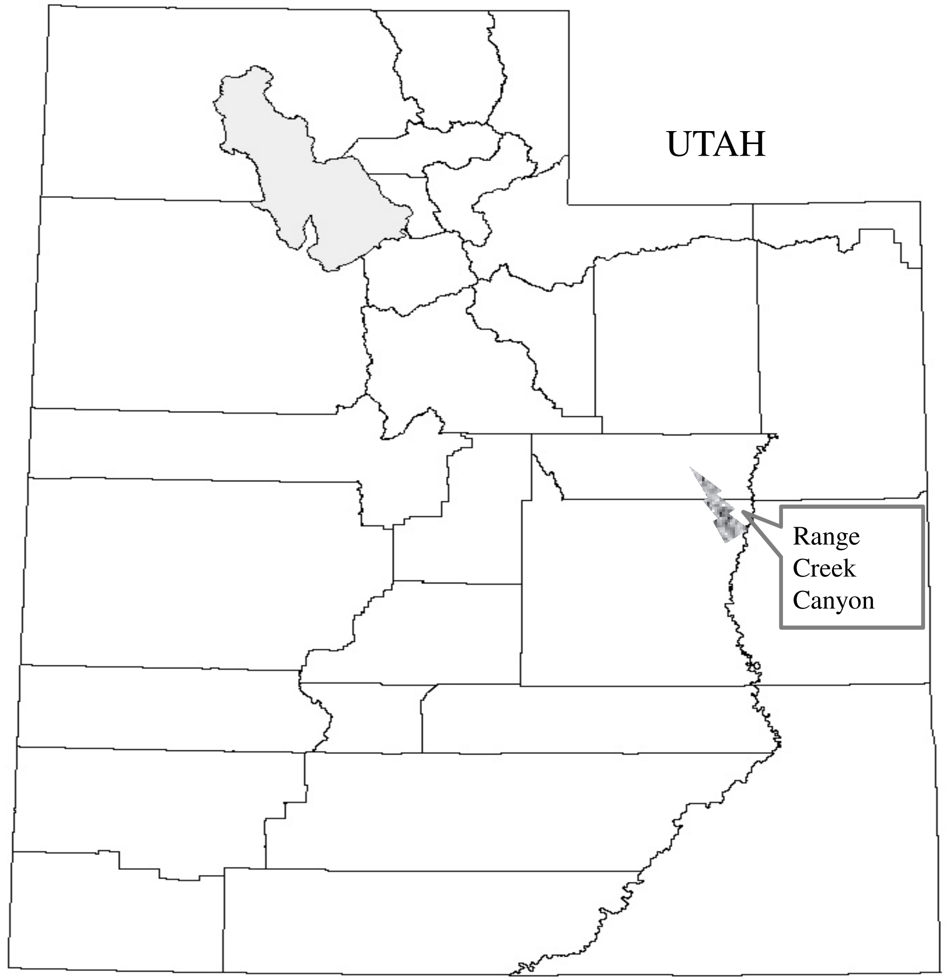

Figure 1. Map showing the location of Range Creek Canyon, UT.

CHAPTER 3

METHODS

Cherry Meadows was selected as a coring location due to its location within the Fremont habitation complex in Range Creek Canyon. The moist conditions of the meadow were likely to support pollen preservation and it was conceivable the mesic setting have supported agriculture during Fremont occupation of RCC. Sediment cores were extracted from Cherry Meadows in the summer of 2005 using a modified Livingstone piston corer and a Dachnowski corer. Two cores were attempted; Core A, referred to as RCCM05 A, was located at 39° 24.301' N, 110° 10.799' W, elevation 1,524 m. This drive was abandoned after encountering an impenetrable root mat. Core B, referred to as RCCM05 B, was collected further north from RCCM05 A, at coordinates 39° 24.311' N, 110° 10.808' W, at the same elevation as Core A. The mossy vegetation mat was collected in whirl packs. Drives one and two (from Core B) were uncomplicated and successful, drive three became lodged in the sediments and a tripod was set up to aid in the removal of the Livingstone device. Drives four and five (from Core B) were collected using the Dachnowski corer. The Dachnowski was used because of its smaller diameter, therefore posing less of a risk becoming immobilized in the sediment profile. All cores and samples were prepared for storage in the field. Cores were wrapped in plastic wrap and aluminum foil, and then secured inside wooden crates for transport. The cores are currently refrigerated at 2.7° C to prevent deterioration and are housed at the Records of Environment and Disturbance Laboratory (RED Lab) located at the University of Utah in Salt Lake City.

RCCM05 B cores 1-3 were analyzed and are presented here. Cores four and five were not analyzed because the stratigraphic integrity of the cores is questionable due to compression of the sediments that was observed in the field during extraction with the Dachnowski cores.

Loss on ignition (LOI) was performed at 4 cm intervals throughout the entire length of the RCCM05 B core. A 1 cc subsample of sediment was placed in a porcelain crucible and heated progressively to 100° C, 550° C and 900° C to determine the percentage of water, organic and carbonate ($CaCO_3$) content, respectively (Dean, 1974). These data can be useful in assessing changes in the productivity and erosion of the Cherry Meadows wetland, adding to our understanding of disturbance events.

Magnetic susceptibility (MS) was performed using a Bartington ring sensor equipped with a 75 mm aperture. All three core segments of RCCM05 B were run horizontally from one end to the other through the ring sensor. Measurements were taken at 1 cm intervals and all the values were recorded in Standard Increment (SI). MS data can detect changes in the sources of accumulating sediments, specifically detecting bedrock-derived material versus organically-derived material. Changes in the MS can often be diagnostic of a fire event or other disturbance event that removes ground cover (e.g., erosional events that follow a fire episode) within the watershed (MacDonald et al., 1991; Gedye et al., 2000).

Five cc sediment subsamples to analyze charcoal concentration were taken at every 1 cm interval throughout the RCCM05 B core to establish a continuous charcoal record for the Cherry Meadows core. Each sample was analyzed by methods described by Whitlock and Larson (2001). Sodium hexametaphosphate was added to the samples to separate the charcoal fragments from the sediment matrix. All sediments were sieved through 125 and 250 micron sieves. These particle sizes have been demonstrated to represent local fires events or episodes (Clark, 1988; Whitlock and Larson, 2001). For each 5 cc charcoal sample, the sieved particles were identified and counted using light microscopy at magnification between 10-40 X. Charcoal was identified based on the following three conditions: uniformly black color, possessing an iridescent sheen, and exhibiting visible cell structure (Clark, 1988). Raw charcoal counts were tabulated and then converted to charcoal accumulation rates (CHAR) by multiplying concentration (units) by the sedimentation rates (cm/yr).

Pollen samples were collected from the RCCM05 B core by removing sediment subsamples in 1 cubic centimeter (cc) increments, at 4 cm intervals throughout the entire length of the core. Each sediment plug (1 cc) was processed to isolate pollen following the lab methods described in Faegri et al. (1989). *Lycopodium*, an exotic spore, was added to each sample as a tracer. The processed samples were preserved in silicone oil. The pollen was then slide-mounted and pollen samples were examined using light microscopy at 500 X. All samples were counted to a minimum of 300 terrestrial grains or 300 *Lycopodium* grains. Laboratory reference slides and literature (e.g. Erdtman, 1952; Bassett et al., 1978; Kapp et al., 2000) assisted in identifying pollen taxa. Pollen grains of Pinaceae (Pine family) were separated into haploxylon (white pine, e.g., limber or pinyon pine) and diploxylon (yellow pine, e.g., ponderosa pine). Haploxylon (diploxylon) pine is distinguished by the presence (absence) of verrucae on the leptoma. Deterioration of Rosaceae (Rose family) pollen was high. The deteriorated Rosaceae grains were combined with *Quercus* (Oak family) if they could not be differentiated from *Quercus*. If they were distinguishable from *Quercus* they were tabulated into as Rosaceae (e.g., *Cercocarpus* and *Amelanchier*). Taxonomy of observed grains was assigned following field observations of the modern phytogeography in Range Creek Canyon. Unknown, degraded or obscured pollen grains were counted and tallied in the total pollen counts. Pollen data are presented as both percentage and influx (grains/cm^2/year). These statistical approaches convey general trends and tradeoffs of taxa relative to one another (percentage) and also convey the actual abundance of each taxa on the landscape over time (influx).

Age model

A chronology for RCCM05 B was established via six ^{14}C AMS dates. Bulk sediment was sent to the Center for Applied Isotope Studies (CAIS) at the University of Georgia for accelerated mass spectrometry (AMS) dating. Samples 40-42cm and 69-70cm are used to constrain the record presented here (Table 1 and Fig. 2).

Samples not included in our analysis include 90-91cm, 109-110cm, 159-160cm and 183-184cm. Sample 90-91cm came back older then our oldest bottom date (183-184cm) and sample 109-110cm came back pMC (percent Modern Carbon). These samples (90-91cm and 109-110cm) were omitted due to postdepositional mixing. It is assumed that some form of bioturbation contaminated our profile at those depths. Samples 159-160cm and 183-184cm (ages) indicate undisturbed sediments; however the record from this portion of the core was not discussed, as the focus of this thesis was the impacts of the Fremont on vegetation and fire regimes post abandonment in the canyon (Fig.2). An age model was created for RCCM 05 B using a second order polynomial: AGE = 1964.716863 - 15.62386534 * X + 0.06025746887 * pow (X, 2) (Table 1 and Fig.2). The data here is presented in A.D. time which puts presents at A.D. 1950. This is different than actual calendar years which puts present at 2005 when the core was collected. To convert the reported age to actual calendar time, 55 years should be added to the value presented.

Table.1 Age-depth relations for sediments from Cherry Meadows, UT

Depth (cm below mud surface)	RED Lab Number RCCM05B (cm)	Lab Number	Source/material	Age (^{14}C B.P.)	CAL (A.D.)
0-1	RCCM05B 0-1	--	--	--	1950
40-42	RCCM05B 40-42	1614	Organic Sediment	508 +/- 41	1404-1441
69-70	RCCM05B 69-70	1979	Organic Sediment	1245 +/-X	1072-1273
90-91	RCCM05B 90-91	1908	Organic Sediment	1670 +/- 40	255-434
109-110	RCCM05B 109-110	1980	Organic Sediment	pMC	--
159-160	RCCM05B 159-160	1615	Organic Sediment	1410 +/- 40	610-656
183-184	RCCM05B 183-184	1909	Organic Sediment	1570 +/- 30	421-547

[a] Y = 1964.716863 - 15.62386534 * X + 0.06025746887 * pow(X,2)

[b] Calendar calebrations determined using CALIB 5.0.2 (Reimer et al., 2004).

Age-depth relations for sediments for Range Creek Canyon, Cherry Meadows, UT. Table shows all radiocarbon dates taken from the core.

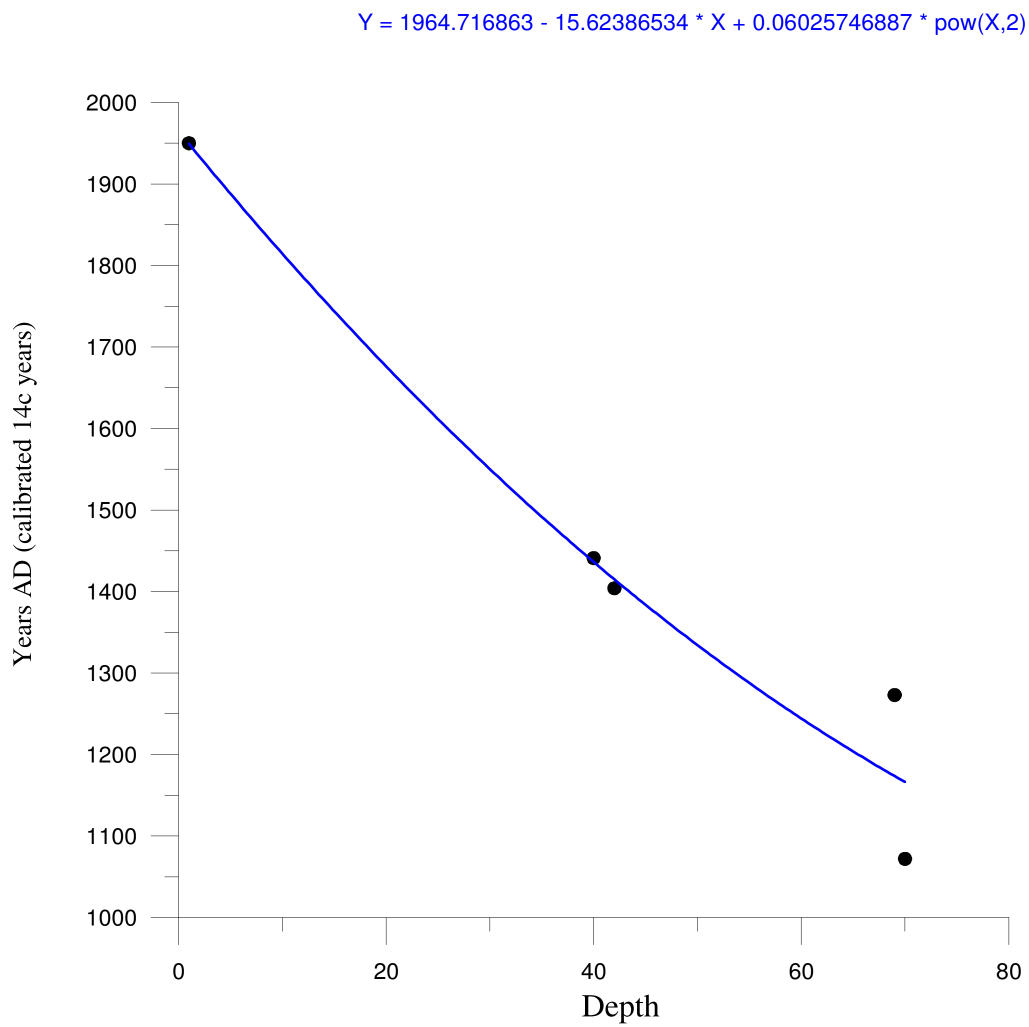

Figure 2. Depth/age relationships for Range Creek Canyon, Cherry Meadows, UT. Second order polynomial: Y = 1964.716863 – 15.62386534 * X + 0.06025746887 * pow (X, 2).

CHAPTER 4

RESULTS

Zone descriptions

Zones were designated based on significant changes in pollen and charcoal abundance. They include Cherry Meadows (CM) 1-3.

CM3: Represents the period A.D. 1166-1475 and captures the time period following or the end of Fremont occupation in the canyon. It also represents the time that the numic tribes presumably inhabit RCC. The CM3 zone is characterized by relatively low pollen influx and charcoal accumulations (Fig.3).

CM2: Represents the period A.D. 1475-1786 and is a period where Range Creek Canyon is presumably uninhabited by any large human population. This zone is generally characterized by large fire events and observable windows between fire events without significant charcoal accumulation (Fig.3). Shifts in vegetative structure are coincident with the proposed abandonment of the canyon by the Fremont (Fig.4).

CM1: Represents the period A.D. 1786-1949 and is the time period that corresponds to European settlement in the Utah region (Hall, 2001; Morris et al., 2010) and the European settlement of RCC in 1885. This zone is characterized as having low fire frequency and the vegetation changes appear to correspond with the European settlement of the canyon (Figs.3 and 4).

CM3 – A.D. 1166-1475

The LOI data (8 values) for the CM3 periods exhibit little variability and these data are presented in Figure 5. The highest value for percent organics is 5% whereas the lowest is 3%. The mean percent carbonate for this zone is 8%. MS data for CM3 show minimal variability, with the highest value for MS is at 10.3 SI and a low at 8.1 SI. The MS average over this period is 8.9 SI. Charcoal influx exhibits little variability during this period, aside from one small peak at A.D. 1354 that rises to 80 particles/cm^2/yr.

The dominant taxa during the CM3 period are *Pinus* (undifferentiated) (pine family), *Artemesia* (sagebrush), *Ambrosia* (ragweed), Asteraceae (sunflower family), (Chenopodiaceae/Amaranthaceae (goosefoot/amaranth family) and *Salicaceae* (willow family). Missing from the CM3 zone are *Pinus* (diploxylon or yellow pines), Cyperaceae (sedge family), Rosaceae/*Quercus* (Rose family/Oak), Carophyllaceae (pink family), Rosaceae (Rose family), (pollen was distinct from Rosaceae/*Quercus*), Moraceae (mulberry family) and *Salix* (willow family). Of the dominant taxa, the most variability can be observed in the pollen percentages of *Pinus* (undifferentiated), *Artemesia*, *Ambrosia*, Asteraceae and Salicaceae. *Pinus* (undifferentiated) has a low of 11% a high of 42% and an average of31%. *Artemesia* has a low of4% a high of 27% and an average of 13%. *Ambrosia* has a low of 5% a high of 31% and an average of 16%. Salicaceae and Cupressaceae are initially absent from the record then rise concurrently from a low of 0% a high of 12% and 5%, respectively. Pollen of Salicaceae averages 3% and Cupressaceae averages 1% over this time period (Fig.4).

The pollen influx records show very little herbaceous pollen being deposited in the meadow, and exhibit little variability over this period. Shrub and tree pollen is similarly complacent, in that influx values increase only slightly during the time period from A.D. 1166-1475 (Fig.3).

CM2 – A.D. 1475-1786

LOI data (6 values) for CM2 show significant variability with the percentage of organics ranging from a high of 21% to a low of 4%. Carbonate values remain fairly stable during this period with a mean of 4% carbonates. MS data for CM2 show the most variability out of all the zones of the Cherry Meadows core, with the highest value being 19.7 SI and the lowest at 2.2 SI. The average magnetic susceptibility values over this zone are 9.3 SI. Charcoal influx exhibits high variability and large magnitude changes where influx peaks exceed 100 particles/cm^2/yr (Fig.5).

The dominant pollen taxa over the CM2 period are *Pinus* (undifferentiated), *Ambrosia*, Chenopodiaceae, Salicaceae (Willow family) and *Artemesia*. All taxa observed throughout the Cherry Meadows core are represented by their pollen during this time period, except Moraceae. Of the dominant taxa, the most variability is displayed by *Pinus* (undifferentiated), *Ambrosia*, Chenopodiaceae and Salicaceae. *Pinus* (undifferentiated) has a low value of 10%, a high of 45% and averages of 25% over this period. *Ambrosia* has a low of 3%, peaks at 16% and averages 9% during this period. Chenopodiaceae exhibits a low of 6%, a high of 28% and averages 17%. Salicaceae is absent from the record at the beginning of CM2 (a low of 0%), peaks with a high of 20% and averages 7% (Fig.4).

Pollen influx has higher variability in CM2 and exhibits greater variability than pollen influx in CM1. The pollen influx shows that herbaceous pollen was low around A.D.

1475 and then rose steadily, peaking at A.D. 1725 and decline at A.D. 1786. The pollen of shrubs and trees increase from A.D. 1475, and peak around A.D. 1550, they both rise and peak again over this time zone, peaking again at A.D. 1786. After A.D. 1786 both tree and shrub pollen decrease slightly (Fig.3).

CM1 – A.D. 1786-1949

The LOI data (2 values) for the CM1 period exhibit little variability, as there are only two samples for this zone. The highest value for percent organics is 24% whereas the lowest is 21%. The mean percent carbonate for this zone is 3%. MS data for CM3 show minimal variability, with the highest value for MS at 1.8 SI and a low at 0.9 SI. The MS average over this period is 1.0 SI. Charcoal influx is observed to be at a consistently low level during this period.

The dominant taxa observed in the Cherry Meadows core CM1 pollen include *Ambrosia* (ragweed), *Artemesia* (sagebrush), *Pinus* (undifferentiated pine), Chenopodiaceae (Goosefoot family), *Sarcobatus* (greasewood), Salicaceae (willow family), Cyperaceae (sedge family), Poaceae (grass) and Moraceae (Mulberry family). Missing from this zone are pollen of *Salix* and *Pinus* (diploxylon). Of the dominant taxa, the most variability is observed in the pollen of *Ambrosia*, *Artemesia* and *Pinus* (undifferentiated). *Ambrosia* has a low of 3% a high of 22% and an average of 9%. *Artemesia* exhibits a low of 3% and high of 11% and averages 5% during the CM1 period. *Pinus* (undifferentiated) has a low of 16% and high of 20% and averages 18% (Fig.4).

The pollen influx data indicate herbaceous species decreasing towards A.D. 1949, while shrubs and trees remain relatively stable, exhibiting only slight increases towards the present day (Fig.3).

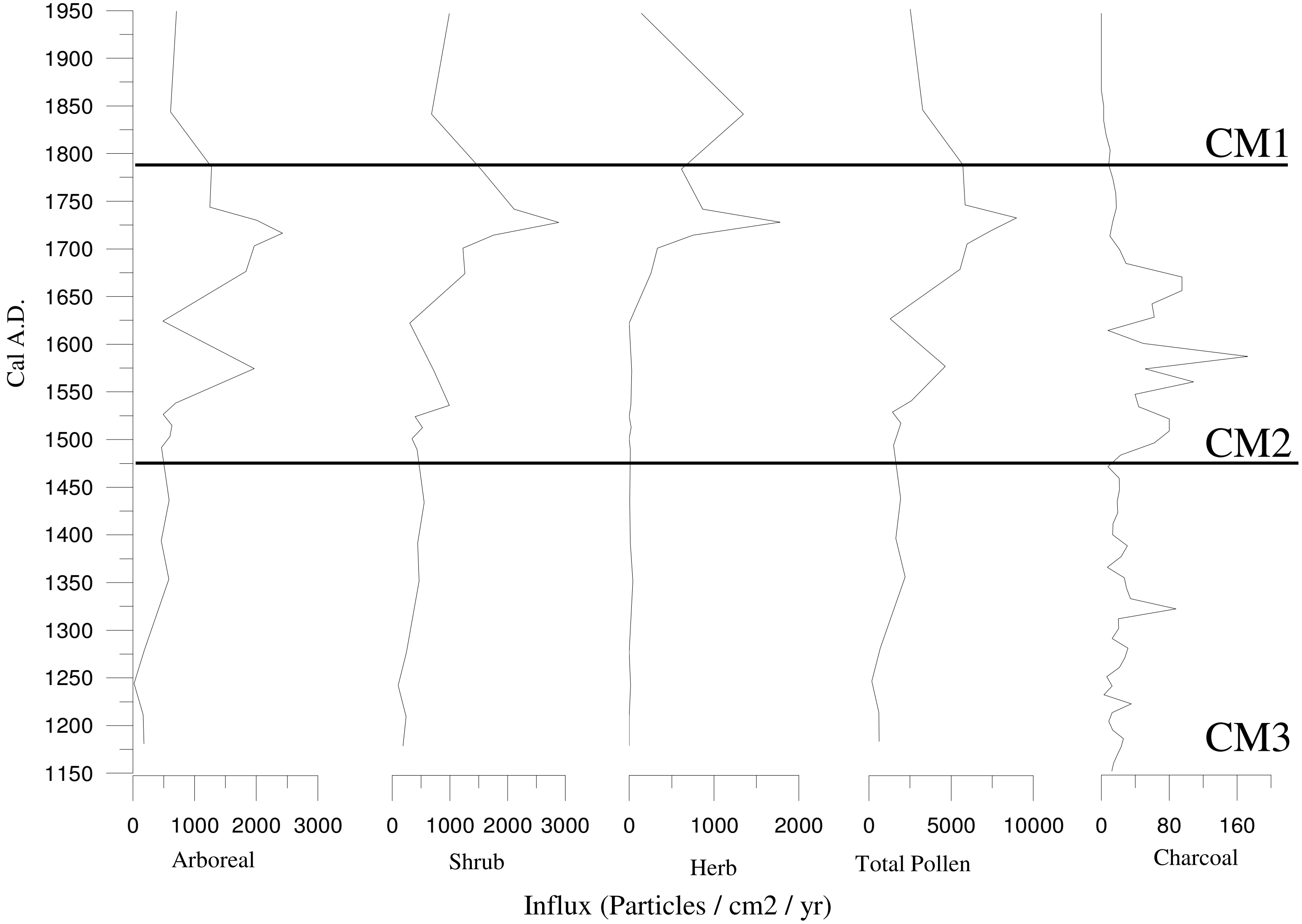

Figure 3. Pollen and charcoal influx for Range Creek Canyon, Cherry Meadows, UT. Zones are divided based on vegetative and charcoal influx changes. Zone 3 shows low pollen and charcoal influx, zone 2 shows higher variability in pollen and charcoal influx and zone 1 shows low pollen and charcoal influx.

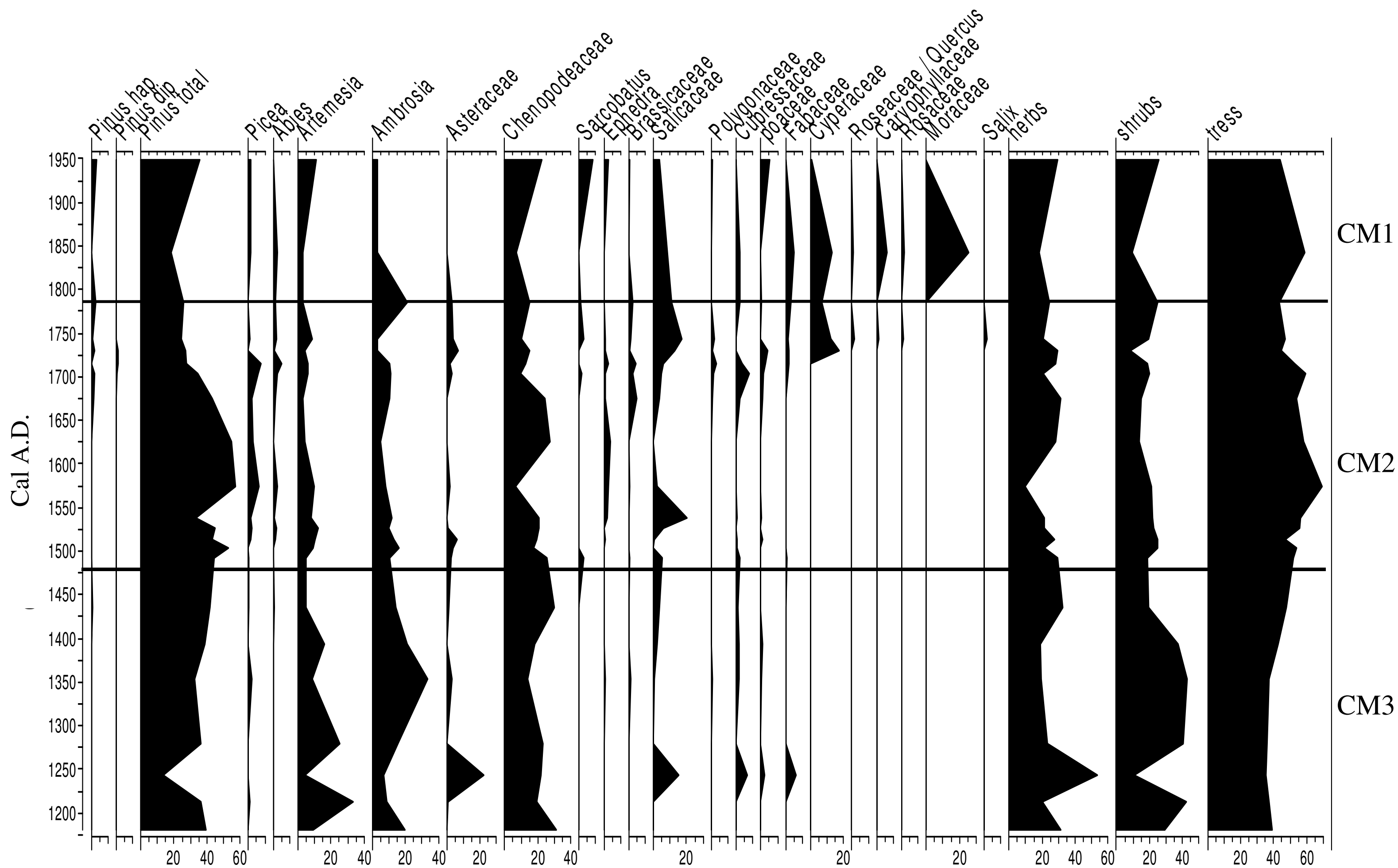

Figure 4. Pollen percentages for Range Creek Canyon, Cherry Meadows, UT. Zones are divided based on vegetation changes. Zone 3 shows pollen changes post-Fremont abandonment of the RCC, zone 2 shows an increase in pollen while RCC is presumably unoccupied and zone 1 contains Moraceae pollen, which is a European settlement indicator.

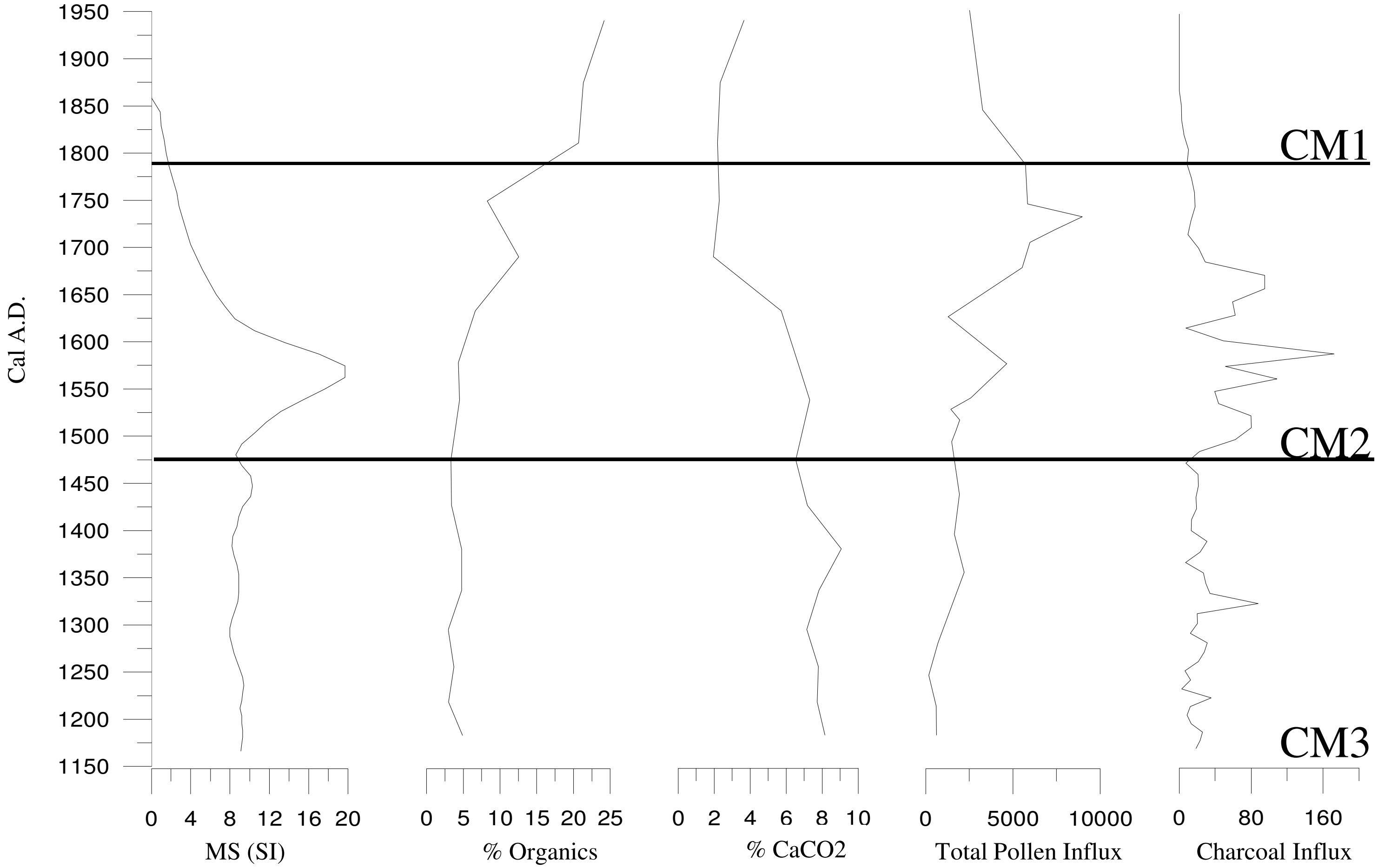

Figure 5. MS, LOI, charcoal and pollen influx for Range Creek Canyon, Cherry Meadows, UT. Zones are divided based on influx changes. Zone 3 shows very low MS, percent organics, percent carbonates and pollen influx and low charcoal influx, zone 2 shows slightly higher variability in MS, low percent organics, percent carbonates and pollen influx. Charcoal influx is high and variable during zone 2. Zone 1 shows low MS, percent organics, percent carbonate, pollen and charcoal influx.

CHAPTER 5

DISCUSSION

Preliminary chronologies for the Fremont occupation apex in RCC center on A.D. 1050 (Metcalfe, 2008). After the mid-eleventh century, it appears that the majority of the Fremont populations dispersed from RCC, though some low-density remnant Fremont or Numic populations may have remained in the canyon. It is possible that either the Fremont or Numic people could have adopted less sedentary ways of life if the environmental conditions did not favor dry corn farming.

The record presented here represents the time period following the apparent peak in Fremont occupation of RCC (after 1050 A.D.). The focus of the paleoenvironmental reconstruction is on two sedimentary indices: charcoal and pollen. The presentation of this record is divided into three temporal windows, CM3, 2 and 1. These time zones are based on changes in charcoal and pollen accumulations. The following discussion is structured around these time periods in an effort to answer the original research questions: 1.) How did the climate affect Fremont occupation patterns? 2.) How did the Fremont affect vegetation and fire during their occupation and after abandonment?

CM3 – A.D. 1166-1475

This period coincides with transition from the warm, wet MCA to the cold, dry LIA, where the cooler temperatures curtailed the northward advance of the NAM which reduced summer precipitation. Pollen and charcoal influx for this period are both low at this time, suggesting low densities of vegetation on the landscape (Fig.3). At A.D. 1350 during the transition from the MCA (warm and wet) into the LIA (cold and dry), the charcoal influx increased (Fig.5). The cooler, drier conditions of the LIA were likely suppressing plant vigor during this time period, which is supported by low pollen influx (Fig.5). The LIA moisture deficits may have also limited accumulations of biomass, thereby reducing woodland brush and fuel, and inhibiting the propagation of high-severity fire. Convective summer storms associated with the NAM would have brought lightening as an ignition source, therefore a reduction of the NAM would have also limited potential (nonhuman) ignitions. Alternatively or additionally, it is possible that the lower charcoal influx during this period could be due to maintenance burning by humans (Fig.3).

Maintenance burning would likely take place annually and would generally be characterized by early season low intensity fires that would remove the annual fuel base (Pyne, 1982, 1995; Blackburn and Anderson, 1993; Keeley, 2002; Stewart, 2002; Abrams, 2008). Maintenance burning would be expressed in a sedimentary charcoal record by a relatively constant influx and a lack of any substantial peaks due to the absence of large intensity fires. It is also possible that humans were collecting charcoal from maintenance burning to use for cooking and warmth (Peterson and Matthews, 1987). Although little is known about Fremont fire use, knowledge of other Native

American populations using fire is well documented (Barrett and Arno, 1982; Russel, 1983; Denevan, 1992; Whitlock and Knox, 2002) and so it is probable that Fremont were using fire in at least a similar fashion. Petersen and Matthews (1987) found high levels of fine charcoal particles in their samples and hypothesized that the Anasazi were using fire to clear land for farming.

The sharp rise from zero of Salicaceae and Cupressaceae pollen in the first century following or on the tail end of occupation (around ~ A.D. 1240) suggests that these taxa might have been exploited by the Fremont as either fuel or construction materials (Fig.6). Many other pollen records show a decrease in aboreal pollen taxa from archaeological sites during occupation (Kohler et al., 1984; Kohler and Matthews, 1984; Petersen and Matthews, 1987; Towner et al., 2009) and numerous records show a post-occupation 'release' in arboreal pollen subsequent to site abandonment (Leopold et al., 1963; Hevly, 1964; Schoenwetter and Eddy, 1964; Martin and Byers, 1965; Madsen and Berry, 1975; Wycoff, 1977; Kohler et al., 1984; Petersen and Matthews, 1987; Kohler and Matthews, 1984; Adams and Petersen, 1999). This interpretation of the Cherry Meadows pollen record is also supported by Towner et al. (2009) who propose that the wood resources the Fremont in RCC would have collected and used would have relied most heavily on species of Salicaceae and Cupressaceae. The amount of Salicaceae and Cupressaceae pollen is greater postabandonment than any other time period in the record, suggesting a large rebound of these two species back on the landscape.

Economically significant pollen, such as Rosaceae, *Ephedra*, *Sarcobatus*, Fabaceae and Poaceae are absent or at very low levels throughout this time period (Fig.4 and 6). It is likely that the Fremont were foraging and utilizing these types of vegetation in RCC, thereby diminishing their palynologial signal in the RCCM05 core during occupation. The significant increases in these pollen types following site abandonment suggests that, in the absence of human exploitation, these taxa flourished or at least were subject to less removal from the landscape (Fig.6). These species are still present on the RCC landscape today (Welsh et al., 2003).

CM2 – A.D. 1475-1786

As the vegetation density and fuel load increased in response to the absence of the Fremont and the proposed maintenance burning, the probability of high-severity or large-scale fire would also rise. This rise in vegetation and charcoal could also be due to the gradual increase in temperature and moisture transitioning out of the LIA. Salicaceae and Cupressaceae during this time period are in higher abundance, which would indicate that there is a higher fuel load available to promote high severity fires. Indeed, the most significant peak in charcoal observed in the RCCM core occurs during this period, within a century of the assumed Fremont abandonment of RCC (Fig. 3 and 5). Cook et al. (2004) suggest, using the Palmer Drought Severity Index (PDSI) reconstructed from tree rings, that this area was relatively dry during this period and becoming progressively drier entering into the industrial period (fig.7). However, it is unlikely that drought is the only mechanism to explain the large fire peak, as moisture deficits can limit fuel production (i.e., plant growth). Another mechanism might be the increase in vegetation (biomass) on the landscape (Fig.3). Similarly, research presented by Knight et al. (2009) from the adjacent Tavaputs Plateau confirms relatively dry conditions in the region surrounding RCC, including five extreme droughts between 1600 and the early 1900s

A.D. Clearly, elevated fuel loads from a release of arboreal species following abandonment and subsequent dry conditions played a significant role in allowing large fires to occur. The second mechanism to explain the large charcoal peak is, during this period Salicaeae, *Ephedra*, Brassicaceae, Salicaceae, Fabaceae, Cyperaceae, Rosaceae/*Quercus* increase in relative abundance from the previous period based on pollen percentages and influx, meaning that these taxa were present in both greater proportion to other taxa found in the record (Fig.3 and 4) and in sheer abundance. Pollen percentages from these taxa would increase during this time when the canyon was presumed not to be occupied because wood resources were not being utilized (Fig.4). This is consistent with the pollen influx for this time period, which is higher in abundance than the previous time period (Fig.3). The correspondence between the timing of abandonment of RCC and the changes in pollen leads to the conclusion that the increases in pollen are probably related, at least in part, to the absence of maintenance burning or resource utilization by the Fremont. Because this is the only continuous long record from this area, other studies have not been able to demonstrate what happens to vegetation and charcoal percentages over a long temporal sequence.

CM1 – A.D. 1786-1949

The CM1 period is characteristic of settlement by Euro-Americans. Charcoal accumulations are low, suggesting that routine maintenance burning by settlers or the grazing of livestock was keeping biomass (fuels) low (Fig.3 and 5). Maintenance burning is possible; however the presence of domesticated livestock on the landscape is the more probable explanation for why charcoal accumulation levels are low for this time period. Grazing most likely began in RCC in the late 1800s (D. Metcalfe, personal communication 2010). The pollen record from RCCM does not show any significant changes in disturbance taxa from grazing, and no sporomiella (an ungulate spore associated with grazing) was found in any of the samples (Fig.4).

Following aquisition of the ranch by the state of Utah several fires have occurred in RCC. At least a half dozen smaller fires and two high-intensity, spatially large (200+ acres) fires occurred in the years 2003 and 2007. The two larger fires removed a great deal of vegetative cover, exposed mineral soil, and consumed many large diameter cottonwoods (*Populus deltoides*) along the riparian corridor of Range Creek. All of these recent fires in RCC were ignited by lightning strikes (D. Metcalfe, personal communication). The intensity of these fires was likely fueled by the increased level of biomass that has accumulated throughout the canyon following the removal of cattle off the landscape as well as the conclusion of land clearing for agricultural practices and/or construction. The relatively high intensity and somewhat short return interval (4 years) of these two fire events suggests that during Fremont occupation, there might have been a incentive to systematically reduce fuel loads, through either land clearing (Fremont) or ungulate grazing (European settlers) for the historic and prehistoric inhabitants (in the case of the Wilcox Ranch). The recent fire events might be analogous in many respects to the large fire episodes recorded in the Cherry Meadows core that occurred following abandonment of RCC by Fremont. There are no other fire histories from the region and this record is unique for this area and also for a post-abandonment ecological assessment.

The pollen of Moraceae shows up in the record in abundance and the pollen of Fabaceae also increases during this period (Fig.4 and 6). Moraceae pollen is an indicator of Euro-American settlement of the canyon, because it is an exotic species to this area, and also because Moraceae *Morus* and Moraceae *Ficus carica* are specimens that were commonly planted in many areas of Utah at the time of settlement (Welsh et al., 2003). Euro-Americans settled in Range Creek Canyon in A.D. 1855 (actual calendar years) (Gerber, 2009). Moraceae pollen shows up in the record at A.D. 1844. When 50 years is added to the radiocarbon corrected A.D. 1844 date of Moraceae pollen, the actual date is A.D. 1894 which agrees with the timing of Euro-American settlement of Range Creek Canyon. Moraceae *Morus* (white mulberry) and Moraceae *Ficus carica* (edible fig) are both fruit trees that can still be observed in many counties of Utah, such as Emery County (*Morus*), and Garfield County (*Ficus carica*) (Welsh et al., 2003). Moraceae *Morus* is currently growing on the Wilcox ranch yet is palynologically indistinguishable from *Ficus.* Increases in Fabaceae pollen can also be interpreted as an indicated of Euro-American settlement because alfalfa (*Medicago sativa*) is often planted as a forage crop for grazing livestock (Hall, 2001). Settlers prefer this plant in xeric environments because it is somewhat drought tolerant and is enticing vegetation for browsing wildlife, deer and elk (Welsh et al., 2003).

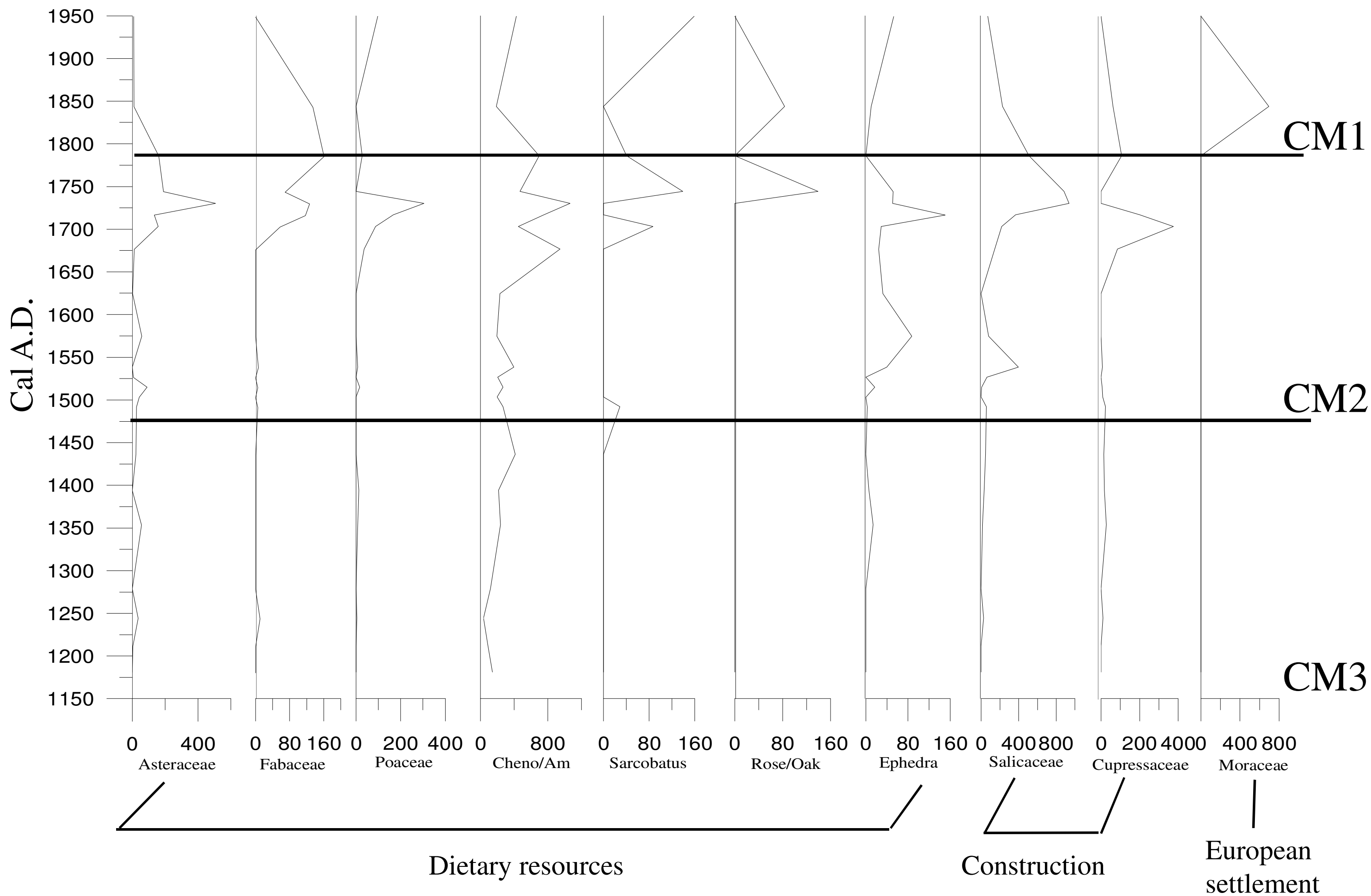

Figure 6. Pollen influx showing Economically Significant Species (ESS) for Range Creek Canyon, Cherry Meadows. Zones are divided based on vegetation changes. Zone 3 shows low pollen influx, zone 2 shows a higher pollen influx and zone 3 shows pollen influx for Moraceae pollen.

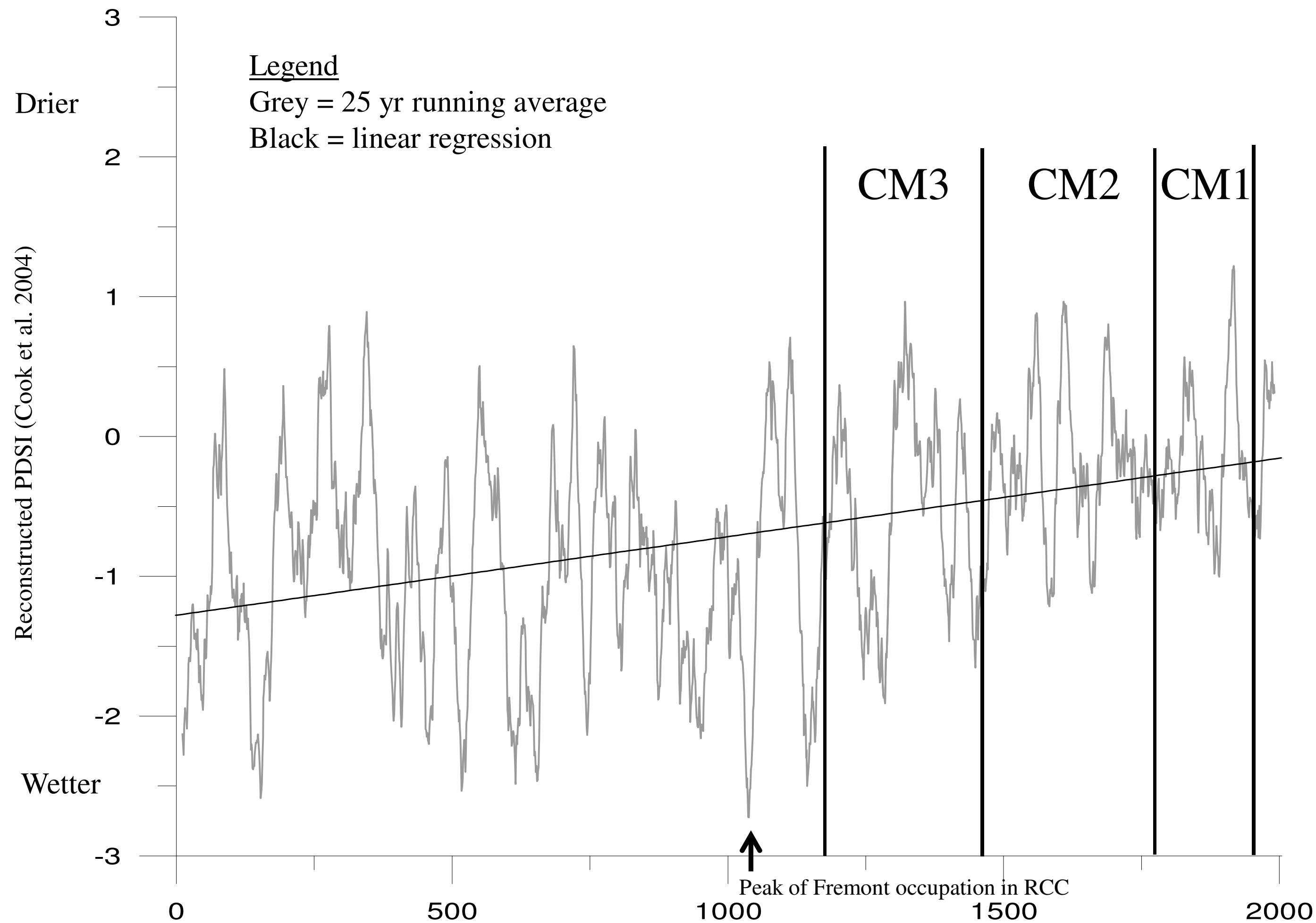

Figure 7. PDSI reconstruction for data point 102 (110.0 W 40.0 N) as reconstructed from Cook et al. 2004. This graph shows the assumed peak of occupation of the Fremont in Range Creek Canyon at ~ A.D. 1050. PDSI for this area shows a trend to drier.

CHAPTER 6

CONCLUSIONS

Range Creek Canyon has been used for sedentary agriculture and then abandoned for that purpose at least twice – the first time by the Fremont between the 11^{th} and 14^{th} centuries and again following the conclusion of the Wilcox ranching operations early in the 21^{st} century. In both instances, it is likely that due to accumulation of fuel from a lack of maintenance burning, significant fire events followed. The post-Fremont vegetation change and fire frequency was interpreted through sedimentary analyses of charcoal sampled from the Cherry Meadows core. Recent fire events were observed by researchers working in RCC. The occurrence of recent events following the cessation of operation of the Wilcox Ranch in RCC suggests that maintenance burning by Fremont populations could explain the low fire frequency observed in the Cherry Meadows core prior to A.D. 1475. Analysis of PDSI data interpreted from tree ring data support the hypothesis that moisture deficits were significant and intensifying at the time the Fremont abandoned RCC. Pollen data from the Cherry Meadows core generally support this interpretation, with the early portion of the record dominated by xeric taxa, with gradual trends in the pollen signal towards more mesic taxa approaching the modern portion of the record and pollen increasing to present day. Increases in abundance of arboreal taxa following abandonment are supported by other pollen records from the southwest, and likely contributed to the occurrence of high severity fire in the absence of utilization of wood resources. Aboreal taxa are higher in abundance postabandonment than any other time period in the record.

The objectives of this study were to see how the climate affected Fremont occupation patterns, and to see how the Fremont affected vegetation and fire in RCC during their occupation and after abandonment. However, bioturbation of the Cherry Meadows sediment profile limited the ability to interpret the portions of the record prior to and during Fremont habitation in the canyon. A more temporally extensive sediment core from RCC would provide an important record of vegetative structure and fire chronology before and during the Fremont inhabitation of the canyon. Additionally, a sedimentary record contemporary with Fremont occupation may yield a pollen record suggestive of what agricultural resources may have been cultivated during this time period.

REFERENCES

Abrams, M.D., Nowacki G.J., 2008. Native Americans as active and passive promoters of mast and fruit trees in the eastern USA. The Holocene 18, 1123-1137.

Adams, K.R., 1994. A regional synthesis of *Zea mays* in the Prehistoric American Southwest. In: Johannessen, S., Hastorf, C.A. (Eds.), Corn and culture in the prehistoric New World. Westview Press, Boulder, pp 273-302.

Adams, K.R., Petersen, K.L., 1999. Environment. In: Lipe, W.D., Varien, M.D., Wilshusen, R.H. (Eds.), Colorado prehistory: A context for the Southern Colorado River Basin. Colorado Council of Professional Archaeologists, Denver, pp. 14-50.

Aikens, C.M., 1966. Fremont – Promontory plains relationships in Northern Utah. University of Utah Press, Salt Lake City, UT.

Anderson, R.Y., 1955. Pollen analysis, a research tool for the study of cave deposits. American Antiquity 21, 84-85.

Anderson, S.R., Hasbargen, J., Koehler, P.A., Feiler, E.J., 1999. Late Wisconsin and Holocene subalpine forests of the Markagunt Plateau of Utah, southwestern Colorado Plateau, U.S.A. Arctic, Antarctic, and Alpine Research 31, 366-378.

Barlow, K. R., 2002. Predicting maize agriculture among the Fremont: An economic comparison of farming and foraging in the American southwest. American Antiquity 67: 65-88

Barrett, S.W., Arno S.F., 1982. Indian fires as an ecological influence in the northern Rockies. Journal of Forestry, 647-651.

Bassett, I.J., Crompton, C.W., Parmlee, J.A., 1978. An atlas of airborne pollen grains and common fungal spores. Biosystematics Research Institute Press, Ottawa.

Benson, L.V., Berry M.S., Jolie E.A., Spangler J.D., Stahle D.W., Hattori E.W., 2007a. Possible impacts of early-11th, middle-12th-, and late-13th-century droughts on western Native Americans and the Mississippian Cahokians. *Quaternary Sciences Reviews* 26, 336-350.

Benson, L.V., Petersen K.L., Stein J., 2007b. Anasazi (Pre-Columbian Native-American) migrations during the middle-12th and Late-13th centuries – Were they drought induced? Climate Change 83, 187-213.

Blackburn, T.C., Anderson, M.K., 1993. Before the wilderness. Ballena Press, Menlo Park.

Bryant, V. M., Hall, S.A., 1993. Archaeological palynology in the United States: A critique. American Antiquity 58, 277-286.

Clark, J.S. 1988. Particle motion and the theory of stratigraphic charcoal analysis: Source area, transportation, deposition and sampling. Quaternary Research 30, 81-91.

Coltrain, J.B., Leavitt, S.W., 2002. Climate and diet in Fremont prehistory: Economic variability and abandonment of maize agriculture in the Great Salt Lake Basin. American Antiquity 67, 453-485.

Cook, E.R., Woodhouse, C.A., Eakin, C.M., Meko, D.M., Stahle, D.W., 2004. Long-term aridity changes in the western United States. Science 306, 1015-1018.

Cutler, H.C. and L.W. Blake. 1970. Corn from the Median Village Site. In: J.D. Jennings, J.D., Mickelson, N.B. (Eds.), Median village and Fremont Culture regional variation. University of Utah Anthropological Papers 95. University of Utah Press, Salt Lake City.

Dean, W.E., 1974. Determination of carbonate and organic matter in calcareous sediments by loss on ignition comparison to other methods. Journal of Sedimentary Petrology 44, 242-248.

Denevan, W.M., 1992. The pristine myth: The landscape of the Americas in 1492. Annals of the Association of American Geographers 82, 369-385.

Erdtman, G.,1952. Pollen morphology and plant taxonomy: Angiosperms. Almqvist and Wiksell, Stockholm.

Faegri, K., Kaland, P.E., Kzyqinski, K., 1989. Textbook of pollen analyses. Wiley, New York.

Fritts, J.C., Smith, D.G., Stokes, M.A., 1965. The biological model for paleoclimatic interpretation of Mesa Verde tree-ring studies. In: Osborne, D. (Ed.), Contributions of the Wetherill Mesa Archaeological Project. Society for American Archaeology, Denver, pp. 101-121.

Gedye, S.J., Jones, R.T., Tinner, W., Ammann, B., Oldfield, F., 2000. The use of mineral magnetism in the reconstruction of fire history: A case study from Lago di Origlio, Swiss Alps. Palaeogeography, Palaeoclimatology, Palaeoecology 164, 101-110.

Geib, P.R., Smith, S.J., 2008. Palynology and archaeological inference: bridging the gap between pollen washes and past behavior. Journal of Archaeological Science 35, 2085-2101.

Gerber, S., 2009. History of Range Creek: Secrets of the Lost Canyon. http://www.kued.org/productions/secretsofthelostcanyon/place/history.html

Hall, S.A. 1985. Bibliography of Quaternary Palynology in Arizona, Colorado, New Mexico and Utah. In: Bryant, V.M., and R. G. Holloway, R.G. (Eds.), Pollen records of Late-Quaternary North American sediments. American Association of Stratigraphic Palynologists Foundation, Dallas, pp. 407-423.

Hall, M., 2001. Repairing mountains: Restoration, ecology, and wilderness in twentieth-century Utah. Environmental History 6, 574-601.

Hevly, R. H., 1964. Pollen Analysis of Quaternary Archeological and Lacustrine Sediments from the Colorado Plateau. Doctoral Dissertation, University of Arizona, Tucson.

Hughes, M. K., Diaz, H.F., 1994. Was there a "Medieval Warm Period", and if so, where and when? Climate Change 26, 109-142.

Kapp, R.O., Davis, O.K., King J.E., 2000. Pollen and spores (2nd ed.). American Association of Stratigraphic Palynologists, New York.

Keeley, J.E., 2002. Native American impacts on fire regimes of the California coastal ranges. Journal of Biogeography 29, 303–320.

Kelly, R.L. 1997. Late Holocene Great Basin prehistory. Journal of World Prehistory 11, 1-49.

Knight T.A., Meko D.M., Baisan C.H., 2009. A bimillennial-lengthtree-ring reconstruction of precipitation for the Tavaputs Plateau, Northeastern Utah, Quaternary Research 3,107-117.

Kohler, T. A., Lipe, W.D., Floyd, M.E., Bye, R.A., 1984. Modeling wood resource depletion in the grass mesa locality. In: Dolores Archaeological Program: Synthetic Report, Bureau of Reclamation, Denver, pp. 99-105.

Kohler, T. A., and Matthews, N.H. 1984. Unraveling cause and effect in changing wood use in the Dolores Project Area. Society for American Archaeology, Portland.

Leopold, L.B., Leopold, E.B., Wendorf, F., 1963. Some climatic indicators in the period A.D. 1200-1400 in New Mexico. UNESCO, Paris, pp. 265-270.

Lindsay, L. W.,1986. Fremont fragmentation. In Coldie, C.J., Fowler, D.D. (Eds), Anthropology of the Desert West: Essays in Honor of Jesse D. Jennings. University of Utah Press, Salt Lake City, pp. 229-251.

MacDonald, G.M., Larsen C.P.S., Szeicz J.M., Moser K.A., 1991. The reconstruction of boreal forest fire history from lake sediments: a comparison of charcoal, pollen, sedimentological, and geochemical indices. Quaternary Science Reviews 10, 53-71.

Madsen, D.B., 1979. The Fremont and the Sevier: Defining prehistoric agriculturalists north of the Anasazi. American Antiquity 44, 711-722.

Madsen, D. B., 1989. Exploring the Fremont. Utah Museum of Natural History. University of Utah Press, Salt Lake City.

Madsen, D.B., Berry, M.S., 1975. A reassessment of northeastern great basin prehistory. American Antiquity 40, 391-405.

Madsen, D.B., Sims, S.R., 1998. The Fremont complex: A behavioral perspective. Journal of World Prehistory 12, 255-336.

Martin, P.S., 1963. The last 10,000 Years: A fossil pollen record of the American Southwest. University of Arizona Press, Tucson.

Martin, P.S., Byers, W., 1965. Pollen and archaeology at Wetherill Mesa. Memoirs of the Society for American Archaeology 19, 122-135.

Marwitt, J. P., 1970. Median village and Fremont Culture regional variation. University of Utah Press, Salt Lake City.

Marwitt, J.P., 1986. Fremont cultures. In: d'Azevedo, W.C. (Ed.), Handbook of North American Indians, Smithsonian Institution Press, Washington, D.C., pp. 161-172.

Massimino, J., Metcalfe, D., 1999. New form for the Formative. Utah Archaeology 12, 1-16.

Metcalfe, D., 2008. Range Creek Canyon. In: Fowler, C.F., Fowler D.D. (Eds.), The Great Basin; People and place in ancient times. School for Advanced Research Press, Santa Fe, New Mexico pp. 117-123.

Mitchell, V.C. 1976. The regionalization of climate in the western United States. Journal of Applied Meteorology 15, 920-927.

Mock, C.J. 1996. Climate controls and spatial variations of precipitation in the western United States. Journal of Climate 9, 1111-1125.

Morris, J.L., Brunelle A.R., Munson, A.S., 2010. Pollen evidence of late Holocene disturbance on the Wasatch Plateau, Utah. Western North American Naturalist 70, 175-188.

Morss, S. 1931. The ancient culture of the Fremont River in Utah: Report on the explorations under the Claflin-Emerson Fund, 1928-29. Harvard University Press, Cambridge.

Newmann, D.E., 1996. Pollen and macrofossil analysis. In: Talbot, R.K., Richens, L.D. (Eds.), Stenaker Gap: An Early Fremont Farmstead. Brigham Young University Press, Provo, pp.123-148.

Petersen, K., 1969. A new variant of the Fremont Moccasin. Utah Archaeology Newsletter 15, 4-9.

Petersen, K. L., 1994. A warm and wet little climatic optimum and a cold and dry little ice age in the southern Rocky Mountains, USA. Climatic Change 26, 243-269.

Petersen, K.L., Matthews, M.H., 1987. Man's impact on the landscape: A prehistoric example from the Dolores River Anasazi, southwestern Colorado. Journal of the West 24, 4-16.

Porter, S.C., 1986. Pattern and forcing of northern hemisphere glacier variations during the last millennium. Quaternary Research 26, 27-48.

Pyne, S. J., 1982. Fire in America: A cultural history of wildland and rural fire. Princeton University Press, Princeton.

Pyne, S.J., 1995. World fire: The culture of fire on earth. Holt Press, New York.

Russel, E.W.B,. 1983. Indian-set fires in the forests of the northeastern United States. Ecology 64, 78-88.

Schoenwetter, J., 1966. A re-evaluation of the Navajo Reservoir pollen chronology. El Palacio 73, 19-26.

Schoenwetter, J., 1970. Archaeological pollen studies of the Colorado Plateau. American Antiquity 35, 35-48.

Schoenwetter, J., Eddy, F. W., 1964. Alluvial and palynological reconstruction of environments, Navajo Reservoir District. Museum of New Mexico Press, Santa Fe.

Spangler, J.D., 2000. One-pot pithouses and Fremont paradoxes: Formative stage adaptations in the Tavaputs Plateau Region of Northeastern Utah. In: Madsen D.B., Metcalf, D. (Eds.) Intermountain Archaeology. University of Utah Anthropological Papers No. 122.

Stewart, O.C., 2002. The effects of burning of grasslands and forests by aborigines the world over. In: Stewart, O.C. Forgotten fires: Native Americans and the transient wilderness. Norman: University of Oklahoma Press: pp. 67-354.

Talbot, R. K., Wilde, J.D., 1989. Giving form to the formative: Shifting settlement patterns in the eastern Great Basin and northern Colorado Plateau. Utah Archaeology 2, 3-18.

Towner, R.H., Salzer M.W., Parks J.A., Barlow K.A., 2009. Assessing the importance of past human behavior in dendroarchaeological research: Examples from Range Creek Canyon, Utah, U.S.A. Tree-Ring Research 65, 117–127.

Welsh, S.L., Atwood, N.D., Goodrich, S., Higgins, L.C., 2003. A Utah flora. Brigham Young University Press, Provo.

Whitlock, C., Knox, M.A., 2002. Prehistoric burning in the pacific northwest. In: Vale, T.R. (Ed.), Fire, native peoples, and the natural landscape. Island Press, Washington, D.C., pp. 195-231.

Whitlock, C., Larsen, C.P.S., 2001. Charcoal as a fire proxy. In: J.P. Smol, J.P., Birks,H.J.B, Last, W.M. (Eds.), Tracking environmental change using lake sediments: Volume 3 terrestrial, algal, and siliceous indicators. Kluwer Academic Publishers, Dordrecht, pp. 75-97.

Winter, J.C., Wylie, H.G. 1974. Paleoecology and diet at Clydes Cavern. American Antiquity 39, 303-315.

Winter J.C., Hogan, P.F., 1986. Plant husbandry in the Great Basin and Northern Colorado Plateau. In: C.J. Condie, Fowler, D.D. (Eds.), Anthropology of the desert: Essays in honor of Jesse D. Jennings. University of Utah Press, Salt Lake City, pp. 110-145.

Wycoff, D.G., 1977. Secondary forest succession following abandonment of Mesa Verde. Kiva 42, 215-231.